Code R Pillar Three: Access to Space

- **In Space Transportation- Goal 10**
- **Achieve with 15 years,**
  - A factor of ten reduction in the cost of Earth orbital transportation
  - A factor of two to three reduction in propulsion system mass and travel time required for planetary missions.
- **Within 25 years,**
  - Enable bold new missions to the edge of the solar system and beyond by reducing travel times by one to two orders-of magnitude.

Customers

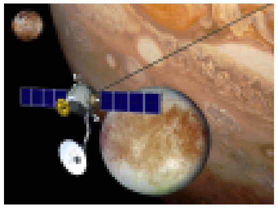
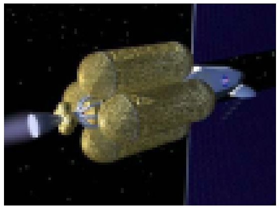
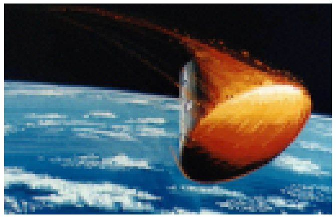
- **NASA, Commercial, DoD Satellites**
- **Robotic Exploration**
- **Human Exploration**
- **Interstellar Missions**

Strategy

- ***Reduce Current Systems***
- ***Dry Mass/ Improve Performance***
- ***Improve Operability & Reliability***
- ***Examine Reusability***
- ***Mature New Concepts &***
- ***Technologies***

In-Space Investment Rationale

- **High Percentage of Projected Launches to Low-Earth Orbit will Require Upper Stages**
  - More Than 70% Go to Geosynchronous Orbit (GEO) or Higher
- **Current Technology (e.g. Inertial Upperstage) Costs $70 – 100M+ per Flight for Large GEO Communications Satellites**
- **Under Current Total Mission Cost Caps, More Ambitious Missions Require Improvements in Propulsion Technologies.**
  - DS-1 Enabled by NSTAR Solar Electric Ion Propulsion.
  - Future Planned Missions Require 2 to 3 Times More Delta V.
  - Rendezvous and Return Missions Will Require Similar Investments in Chemical PropulsionSystems and Aerocapture Technologies.
- **Per Current Studies, Human Exploration Missions to Mars, In-Space Transportation Costs are Projected to be Higher than Earth-to-Orbit Costs.**
  - Affordable In-Space Transportation is Enabling for Human Exploration Missions (Lighter Weight Systems, Shorter Trip Time.)
  - In-Situ Propellants offer Significant Potential to Reduce Mission Costs.
- **New Opportunities to Explore Beyond the Outer Planets Will Require Unparalleled Technology Advancement and Invention.**

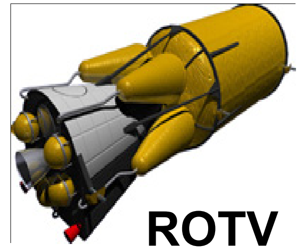

Space Transfer Technology: Customers and Stakeholders

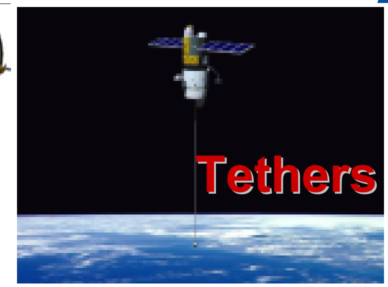
- **Mission Categories and Customers**
  - Earth Orbital, Commercial, NASA, DoD
  - Interplanetary Transfer, NASA Code S, HEDS
  - Orbit Insertion, NASA Code S, HEDS
  - Ascent/Descent, NASA Code S, HEDS

- **Close coordination with Air Force and Industry is maintained**
  - Hall Thruster and other electric propulsion systems
  - Cryogenic fluid management
  - Solar thermal propulsion technology
  - Tether systems

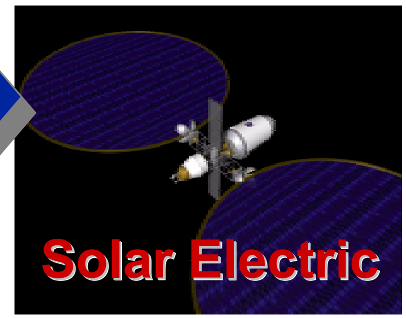
Scope of Space Transfer Technology Project

Orbital Transfer Vehicles





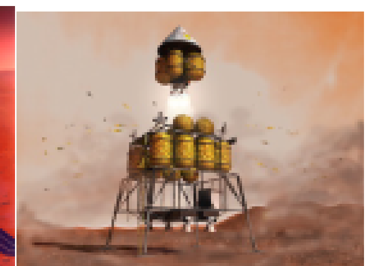
Interplanetary Transfer Stages



Planetary Capture

Ascent/Descent Stages

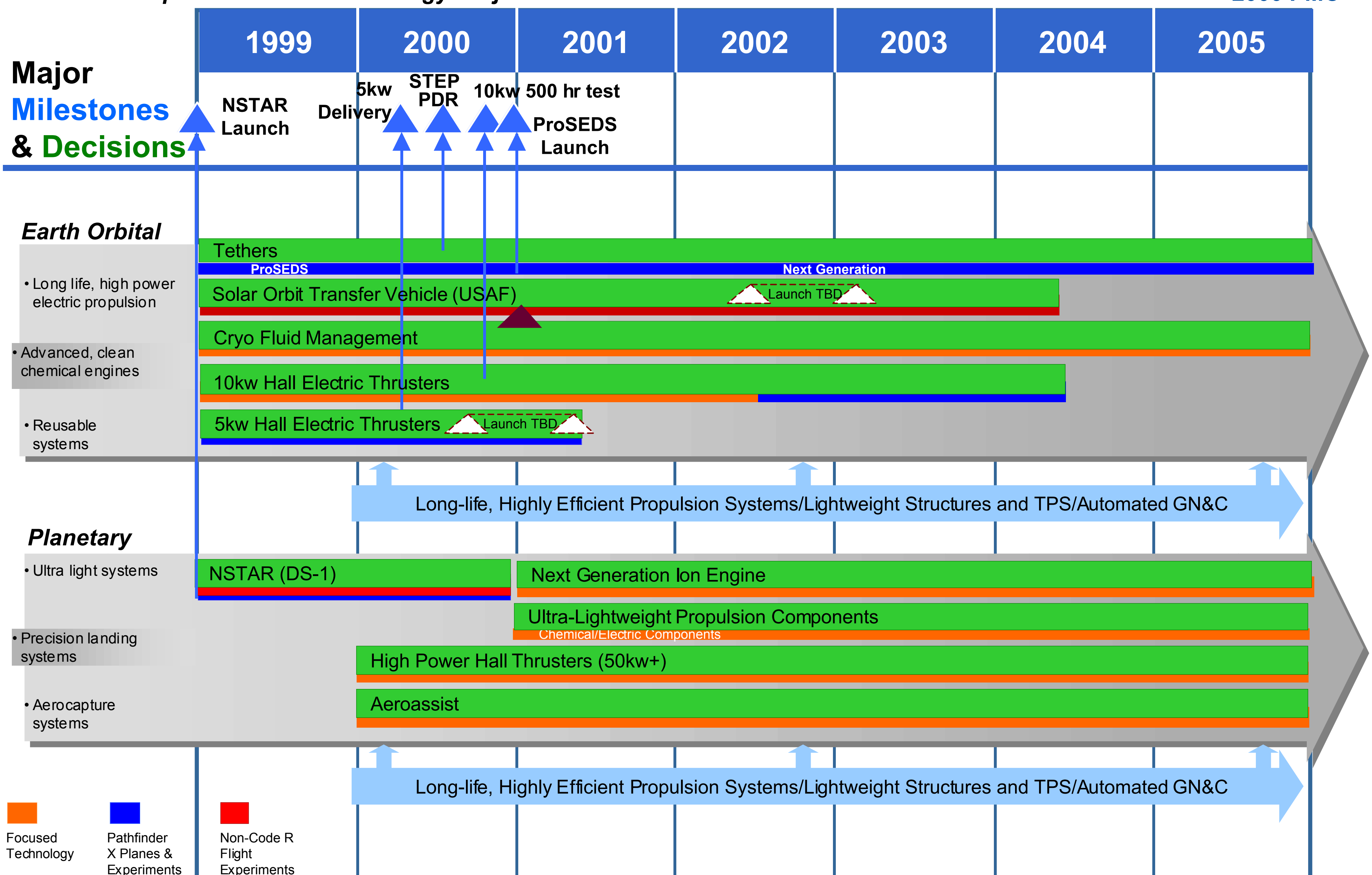
Sample return



In-Situ Prop/
Ascent Chem
Prop Stage

Space Transfer Technology Roadmap

Space Transfer Technology Project — **2000 PMC**



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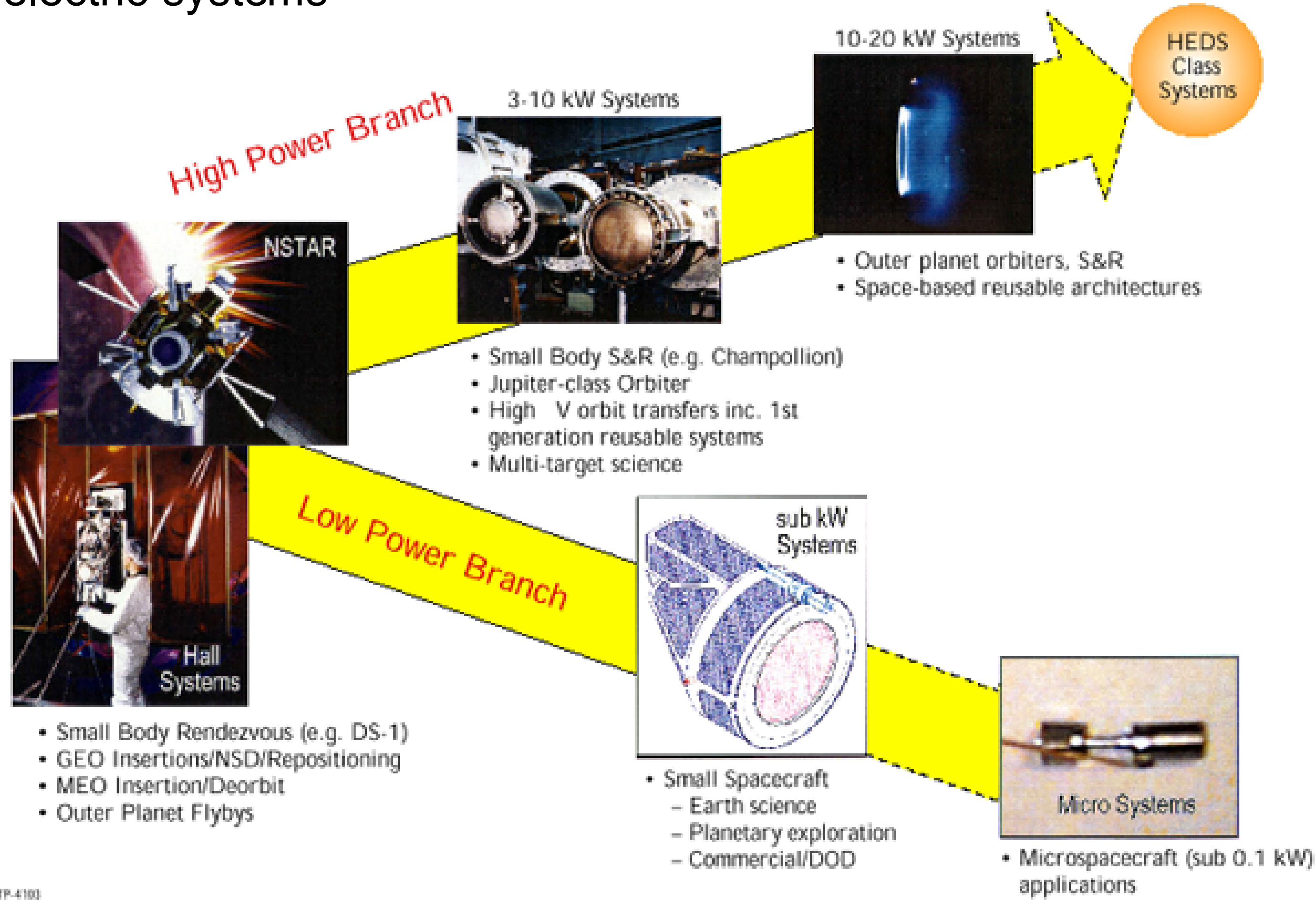
ASTP Space Transfer Technology: Electric Propulsion

Space Transfer Technology Project **2000 PMC**

♦ Goals

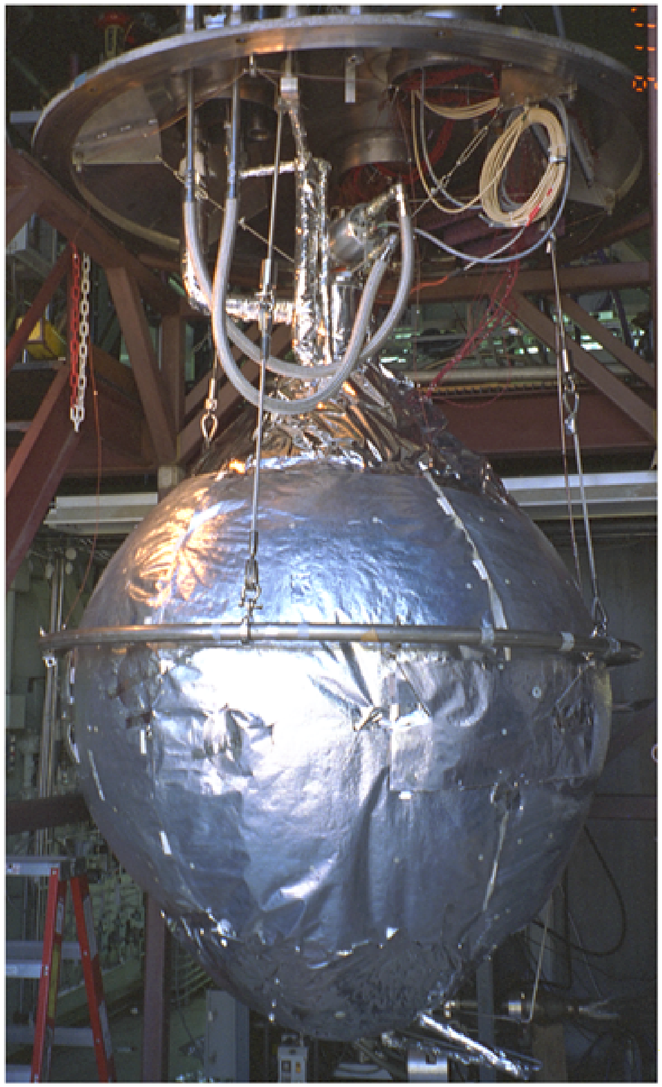
- Advance electric propulsion systems to reduce mass and cost of orbital transfer missions
- Enable interplanetary missions through use of solar electric systems



ASTP Space Transfer Technology: Electric Propulsion

- **Intercenter working group has being established for this technology area to help determine:**
  - Project content
  - Technology roadmaps
  - Center funding distributions
- **First working group mtg held in Nov. 99**
  - Participants from mission organizations:
    - GSFC, JSC, JPL, MSFC
  - Participants from technology organizations:
    - GRC, JPL, MSFC, JSC
- **<u>NASA Centers:</u> GRC (Lead), JPL, MSFC**

ASTP Space Transfer Technology: Cryo Fluid Management



♦ Goals:

- Develop capability to provide long-term storage of cryogenic propellants
- Demonstrate concepts for zero-g pressure control
- Develop zero-boil-off concepts for cryogenic propellants
- Future-X funded flight experiment, Cryo Propellant Gauge (managed @ GRC, support @ MSFC)

♦ Mission/Technology Applications:

- Advanced Cryogenic upper stages
- Solar Thermal Propulsion
- High Energy Transfer stages
- In-situ propellant utilization
- HEDS Applications - Transportation and surface

ASTP Space Transfer Technology: Cryo Fluid Management

- **Intercenter working group is being established for this technology area to help determine:**
  - Project content
  - Technology roadmaps
  - Center funding distributions

- **NASA Centers: ARC, GRC, MSFC, JSC, KSC**

- **Major milestone completed in April 1999 - LH_2 tank with Thermodynamic vent system for propellant supply of 30 day Solar Thermal mission simulation.**

ASTP Space Transfer Technology: Aeroassist

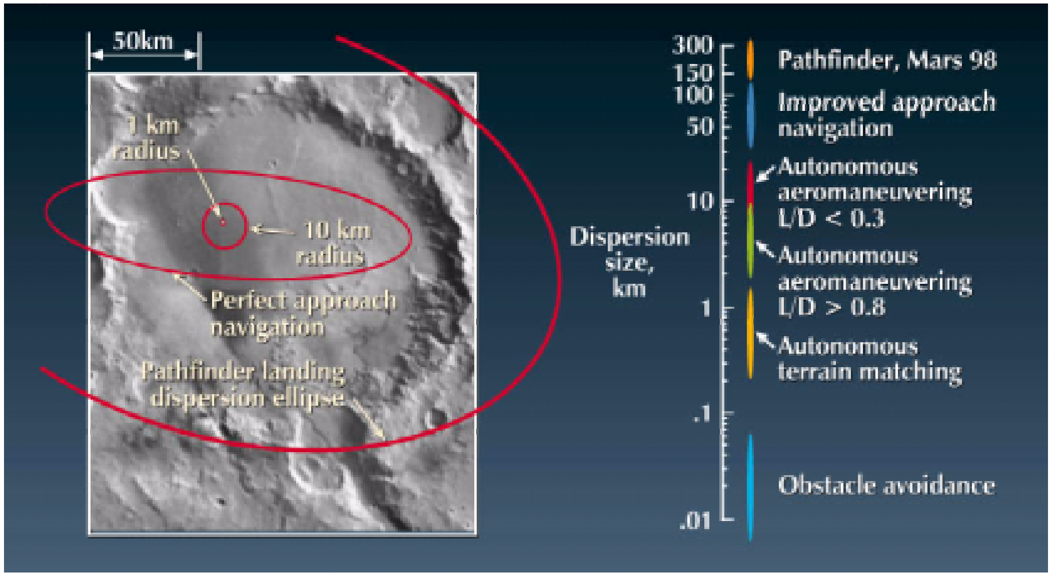
Space Transfer Technology Project **2000 PMC**

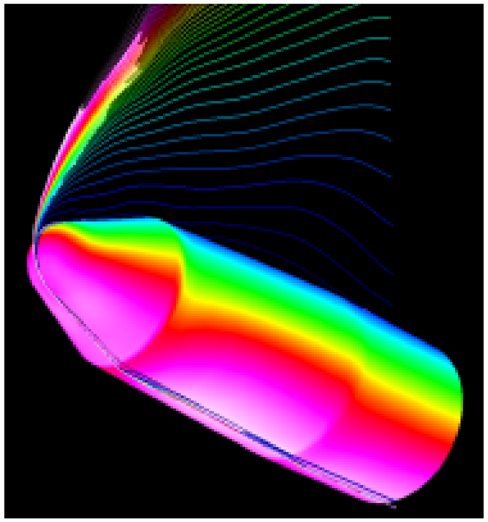
♦ Goals:

- Aeroassist technologies lowers propulsion system requirements for planetary mission; reduces launch mass, enables precision landing, provides flexibility in mission scenarios
- Key technology areas: Aerothermodynamics, Thermal Protection Systems, GN&C, Vehicle Design

♦ Mission/Technology Applications:

- Aerocapture at planetary surface
- Direct entry at planetary surfaces
- Aero-gravity assist mission
- Earth reentry vehicles
- Aerobraking
- Precision Landing





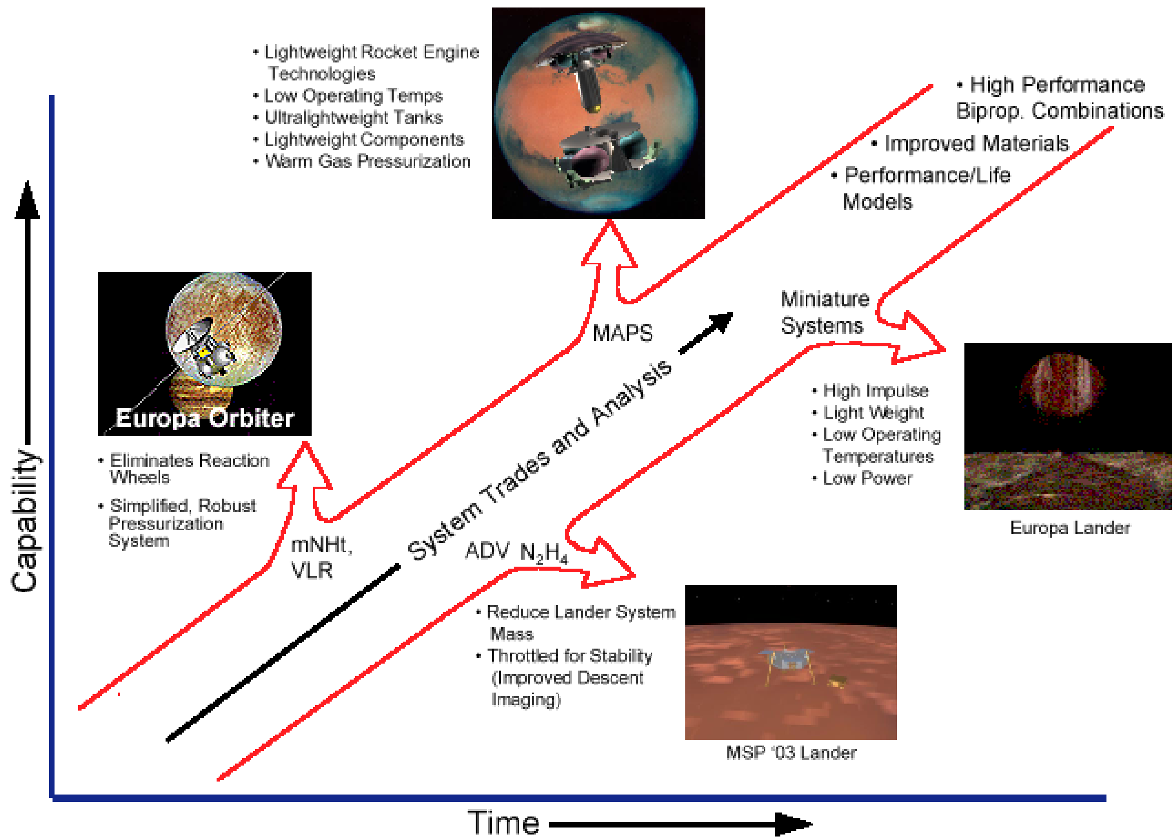
ASTP Space Transfer Technology: Aeroassist

- **Intercenter working group is being established for this technology area to help determine:**
  - Project content
  - Technology roadmaps
  - Center funding distributions

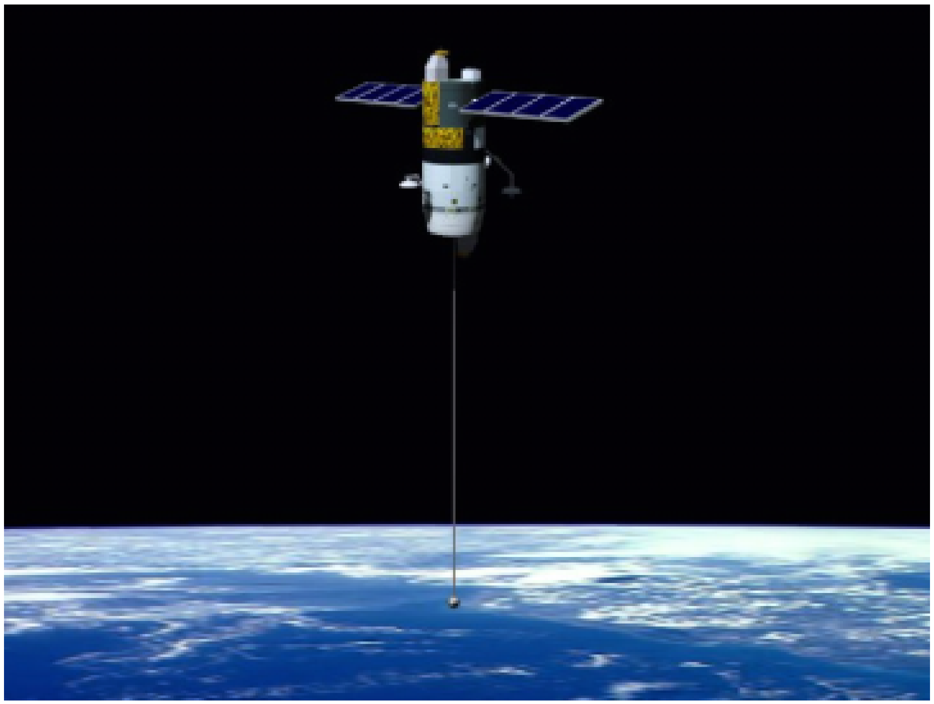
- **<u>NASA Centers:</u> LaRC (Lead), ARC, JSC, JPL, MSFC**

ASTP Space Transfer Technology: Lightweight Components

- **Goals:**
  - **Dramatically reduce dry mass of spacecraft propulsion systems**
    - Feed system components
    - Lightweight composites - linerless tanks
    - Lightweight thrust chambers
  - **Lightweight systems lower cost and development time**
  - **Application for electric propulsion systems, chemical, and cryogenic systems**



ASTP Space Transfer Technology: Tethers



Description

- **Goals:**
  - Develop mission applications for momentum exchange tether systems
  - Define next mission for electrodynamic tethers (follow-on to ProSEDS)
  - Future-X funded flight experiment, ProSEDS (managed @ MSFC)

- **Applications:**
  - De-orbit systems for spent stages and satellites
  - Reusable orbit transfer vehicle
  - Space station reboost
  - Stationkeeping and repositioning of satellites
  - Jupiter and Europa exploration missions
  - Payload delivery to higher orbits and beyond

Major Accomplishment: In-space Prioritization Process

Evaluation Criteria
- Technical
- Programmatic

Candidate ISP Technologies
- By Mission Category
- Pivot Tech. for each Cat.
- White Papers
- Briefings

Facilitated Collaborative AHP

- Pairwise comparisons of candidate technologies against evaluation criteria
- Collaborative data entry through facilitation S/W

Prioritized Technologies
- Technically
- Programmatically
- By Mission Category
- Across all the above factors

Space Transfer Technology Project Milestones

- ♦ **2QFY00 - Deliver 5KW hall thruster propulsion system to a commercial satellite for integration(EXPRESSexperiment)** — G
  - Output:Thruster delivered to spacecraft ready for integration
  - Outcome:Allows increased payload capability over chemical systems
- ♦ **3QFY00 - STEP Preliminary Design Review** — G
  - Output:Preliminary design of flight experiment to demonstrate increased transportation capability of electrodynamic tether systems
  - Outcome:Allows detailed design of the flight experiment to be conducted. Ultimate demonstration is for a propellantless low-cost orbit transfer system using electrodynamic tether.
- ♦ **4QFY00 - Demonstrate electrodynamic tether propulsion (ProSEDS)** — G
  - Output:In-flight Demonstration of altitude lowering of a Delta II 2nd stage
  - Outcome:Provides demonstration of low-cost system to remove spent stages and satellites from orbit, without using onboard propulsion system.
- ♦ **TBD, based on SOTV launch - Demonstrate capability to precisely measure cryogenic propellant levels in zero-g** — G
  - Output:In-flight demonstration of mass gauging capability
  - Outcome:Allows accurate measurement of propellants on orbit, resulting in lowering propellant loading for uncertainty. Ultimate outcome is reduced mass chemical systems